

# Transition to Sustainable Energy Services (TRANSES)

A joint research program  
NTNU / SINTEF / MIT / Chalmers  
2004 - 2008

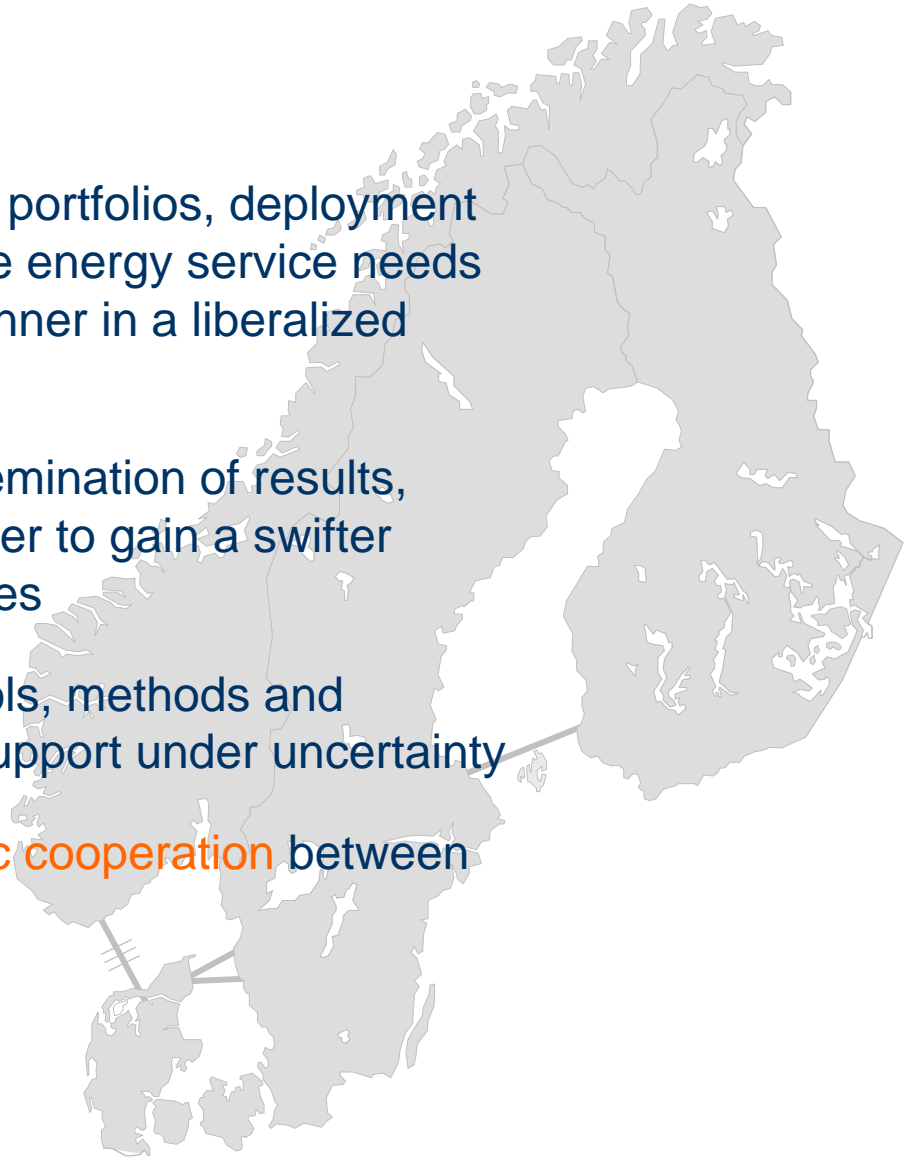
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# Objectives

- **Outline and evaluate** likely technology portfolios, deployment paths and policy options to meet future energy service needs in a cost-effective and sustainable manner in a liberalized energy market environment
- **Create an international arena** for dissemination of results, dialogue and exchange of ideas in order to gain a swifter transition to sustainable energy services
- **Provide a toolbox** of computational tools, methods and databases for analysis and decision support under uncertainty
- **PhD education** and long-term **scientific cooperation** between the institutions involved



## Transition to Sustainable Energy Services (TRANSES)

# Sponsors

- Project idea created by Norsk Hydro, The Industry's Innovation Fund at NTNU and Dept. of Energy and Process Engineering, NTNU
- Current sponsors:
  - Norsk Hydro
  - Norske Shell
  - Statoil
  - Statkraft (Norw. State Power Company)
  - Statnett (Norw. Grid Company)
  - Statsbygg (Norw. State Building Operator)
  - Enova (State agency for energy efficiency and renewable energy)
  - ...



## Transition to Sustainable Energy Services (TRANSES)

### Scientific partners

- The Department of Energy and Process Engineering, NTNU
- The Department of Electrical Power Engineering, NTNU
- The Department of Architectural Design, History and Technology, NTNU
- SINTEF Energy Research
- The Laboratory For Energy and the Environment (LFEE) at MIT
- The Department of Energy Technology, Chalmers
- Others....?



NTNU



MIT



Chalmers



## PhD Studies

- A number of coordinated PhD studies and possibly PostDoc positions will be initiated at the different participating institutions. Suggested themes are:

- Decision support under uncertainty
- Efficient energy use / Building technology
- The end users role and behaviour
- Emissions trading and green certificates
- Hydrogen as future energy carrier
- CO<sub>2</sub> free technology
- Life Cycle Assessment
- ...



# Samples of TRANSES challenges

## 1. Clean Nordpool

- Can **market mechanisms** be utilized to gain a swifter transition to sustainable energy services?

## 2. Rational Regulation

- What set of **regulations** on economic, environmental and other aspects provides the best **incentives** to industry and consumers?

## 3. Efficient Utilization

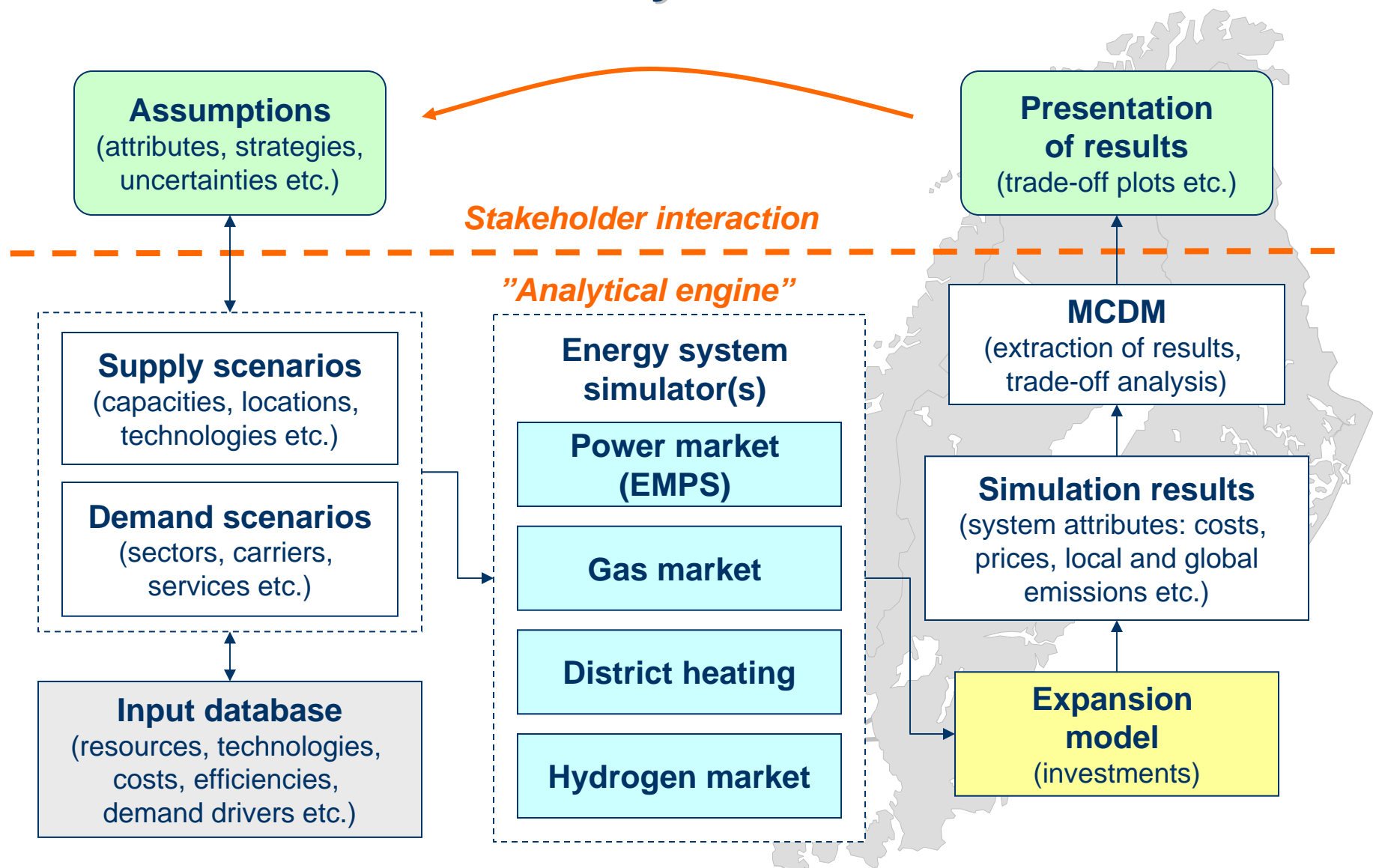
- What role can **new technology** play, and in which time perspective?
- The **end-users role**, his needs and his behaviour are included in this evaluation

## 4. Coordinated Carriers

- How can different energy carriers and energy technologies be **coordinated** in the economically and environmentally best way possible?

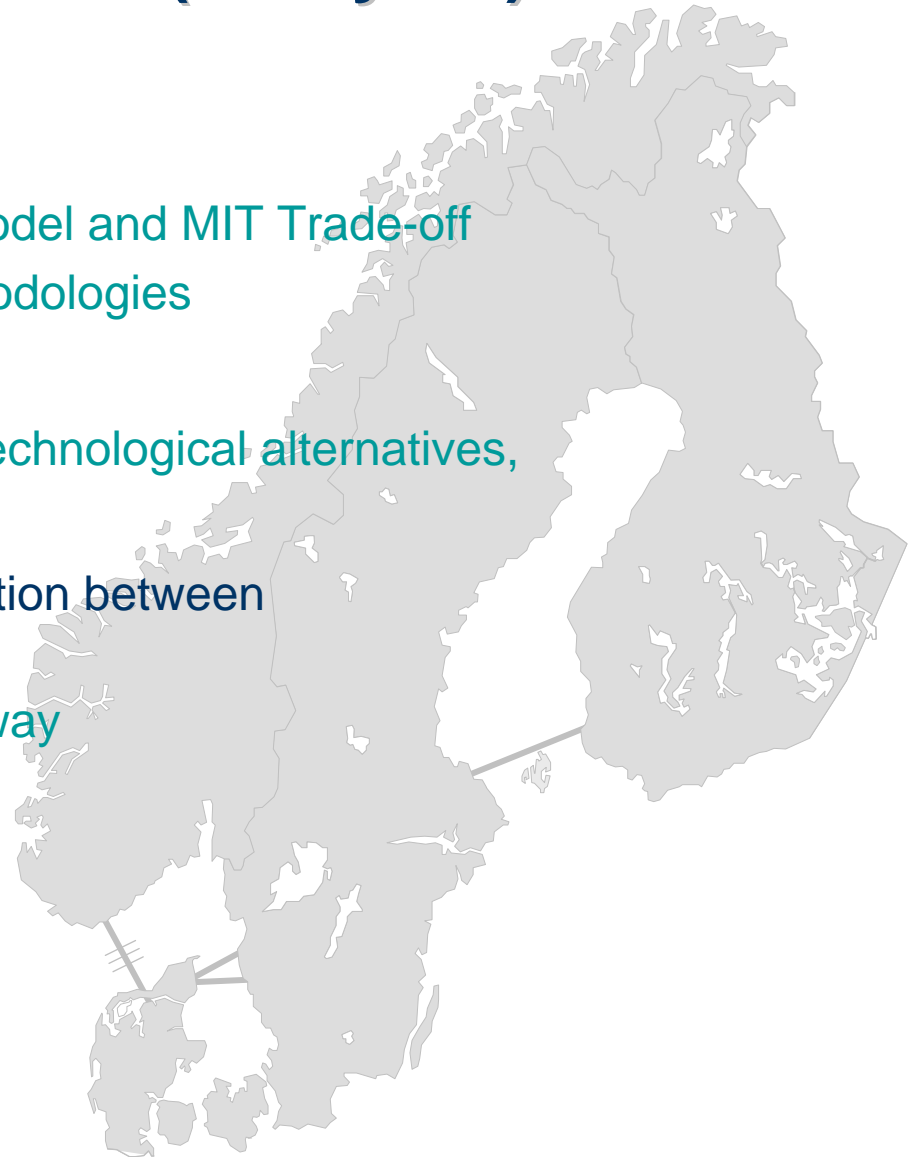


# TRANSES analytical framework



# TRANSES – current activities (first year)

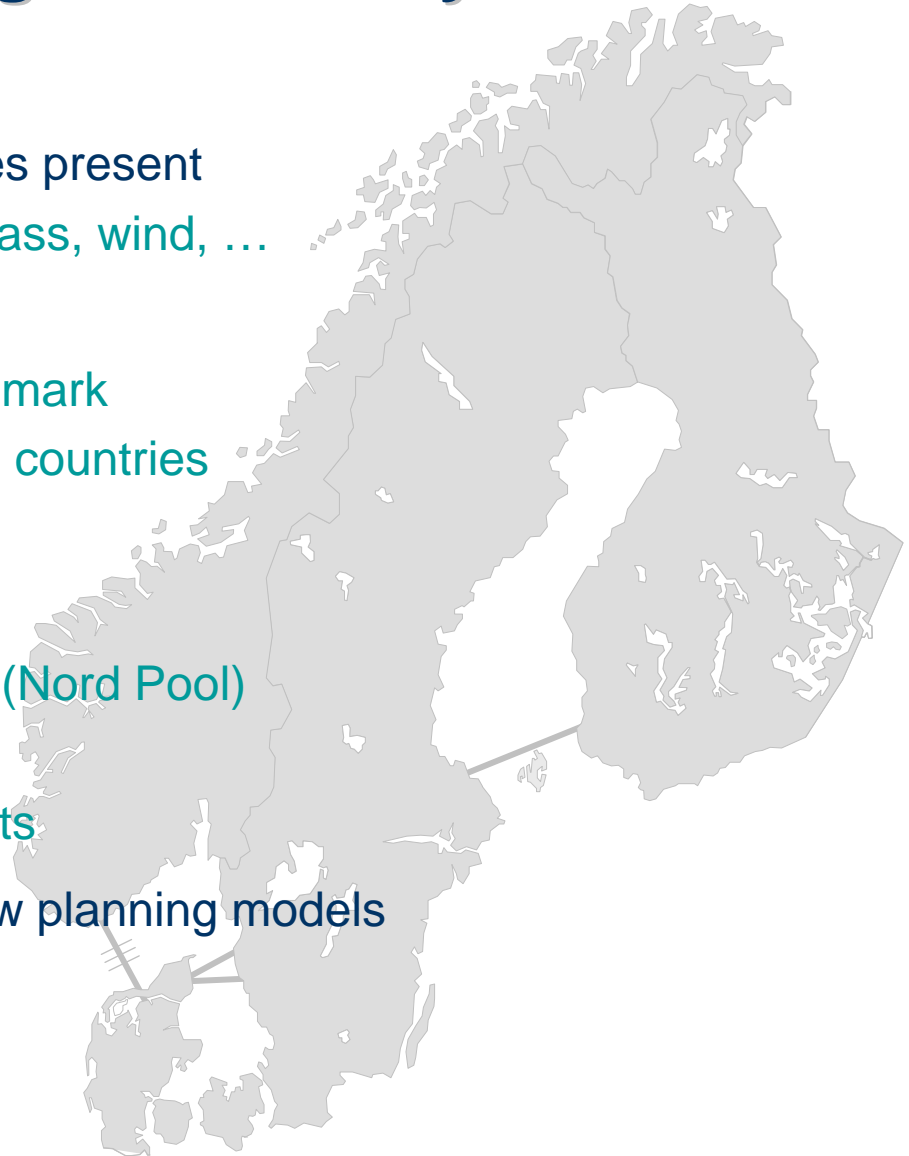
- Identify adequate analytical tools
  - Preliminary studies with EMPS model and MIT Trade-off
  - New or existing models and methodologies
- Input data and assumptions
  - Current system, new resources, technological alternatives, macroeconomic trends etc.
- Establishing efficient ways of cooperation between participating institutions
  - Core activities in Trondheim, Norway
- Employing PhD students
- Establish stakeholder group
  - Initial stakeholder meetings
  - Extend the funding for the project



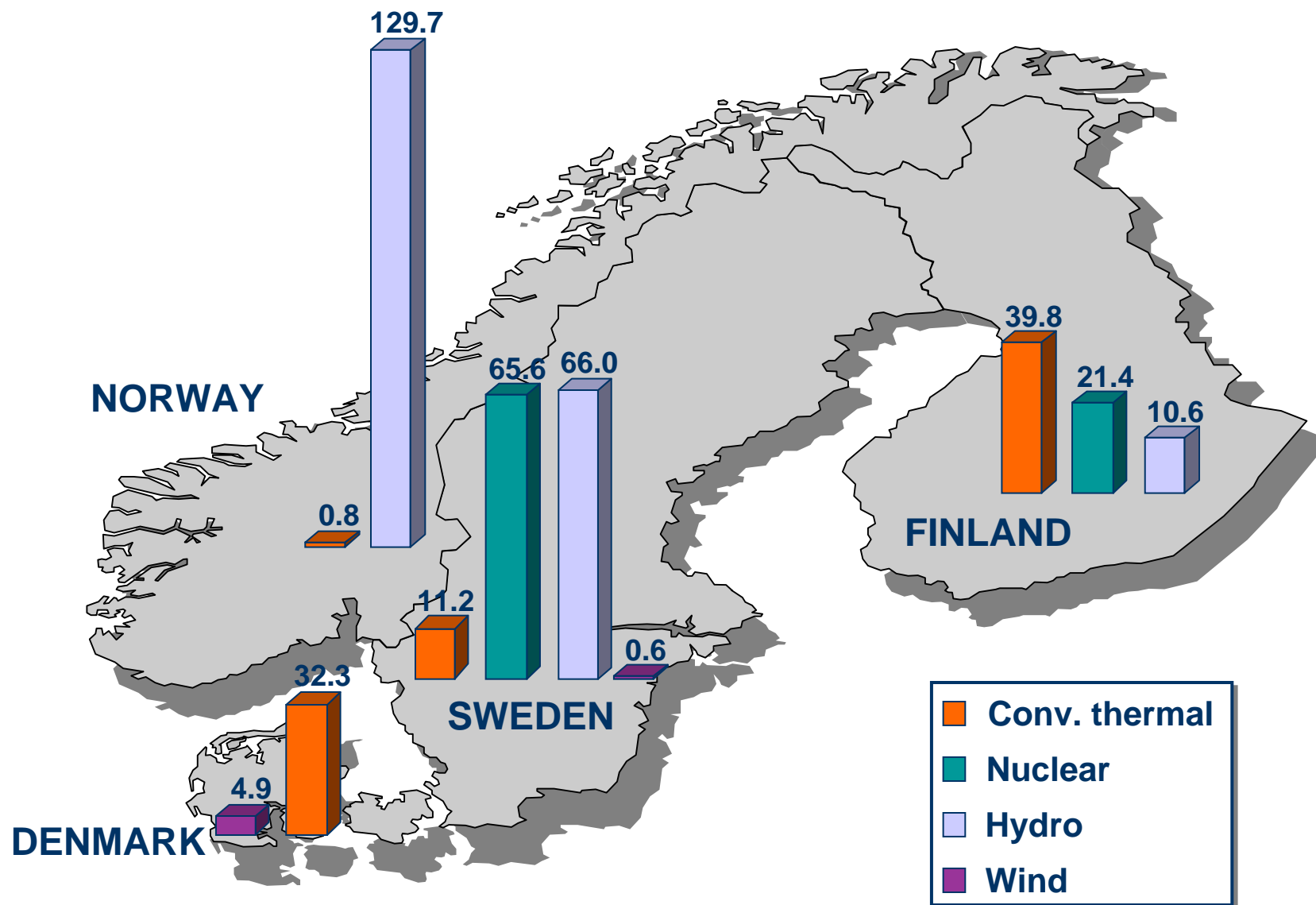


# Scandinavia – an ideal region for analysis

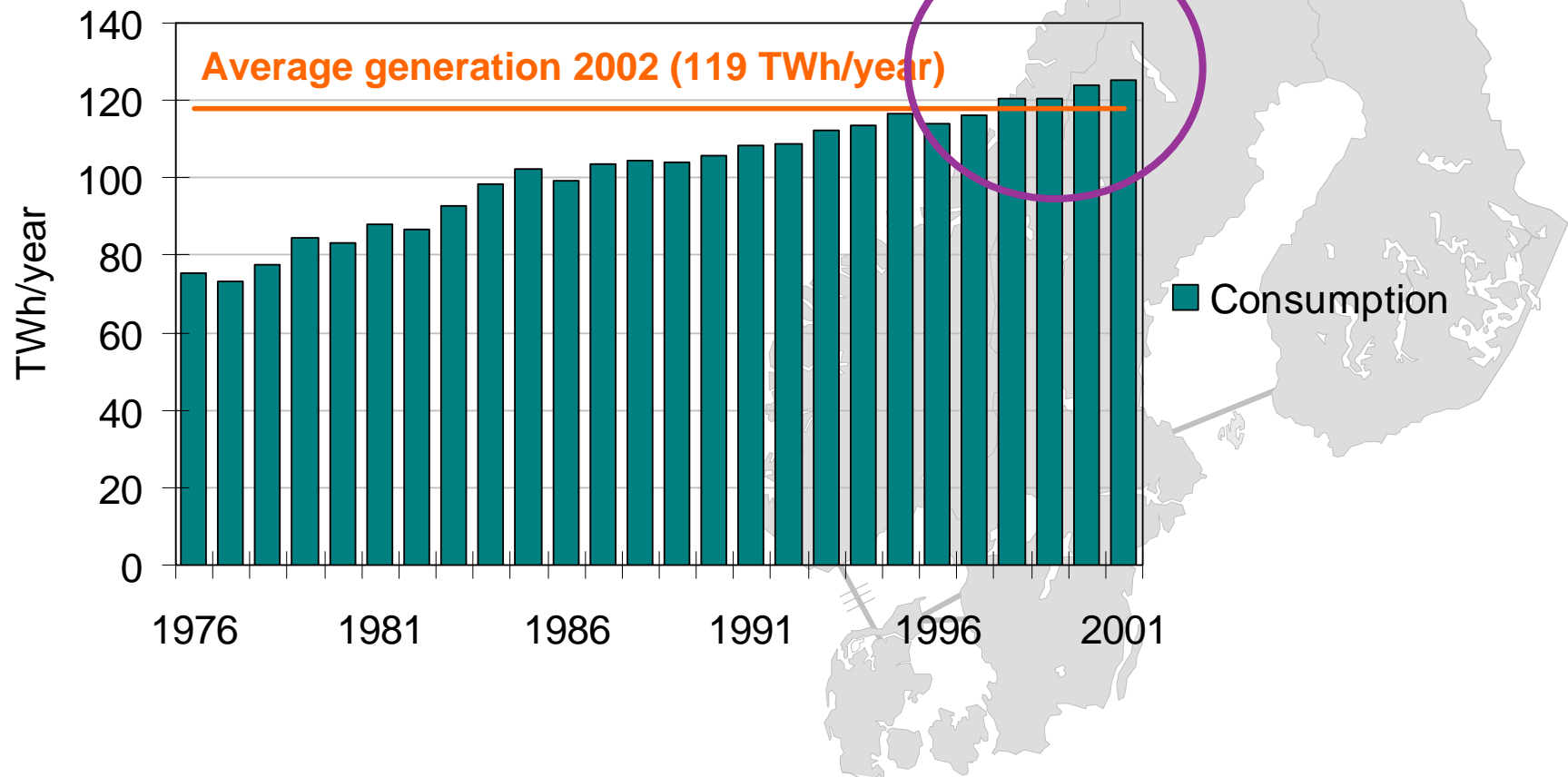
- All major energy resources/technologies present
  - Hydro, nuclear, coal, oil, gas, biomass, wind, ...
- Limited geographical scope
  - Norway, Sweden, Finland and Denmark
  - Limited connections to neighboring countries
  - Transparency (data availability)
- Market and competition
  - Common liberalized power market (Nord Pool)
  - Emerging European gas market
  - Emerging “green certificate” markets
- Good region for experimenting with new planning models and methodologies



# Electricity Generation in Nordel 2002 (TWh)



# Generation capacity vs. consumption 1976 - 2001



# Demand uncertainties

## ■ Driving forces for growth in electricity demand

- Substitution of oil to electricity
- Increased comfort (kWh/m<sup>2</sup>)
- Increased activities (m<sup>2</sup> and NOK)
- Domestic changes (m<sup>2</sup> per capita)

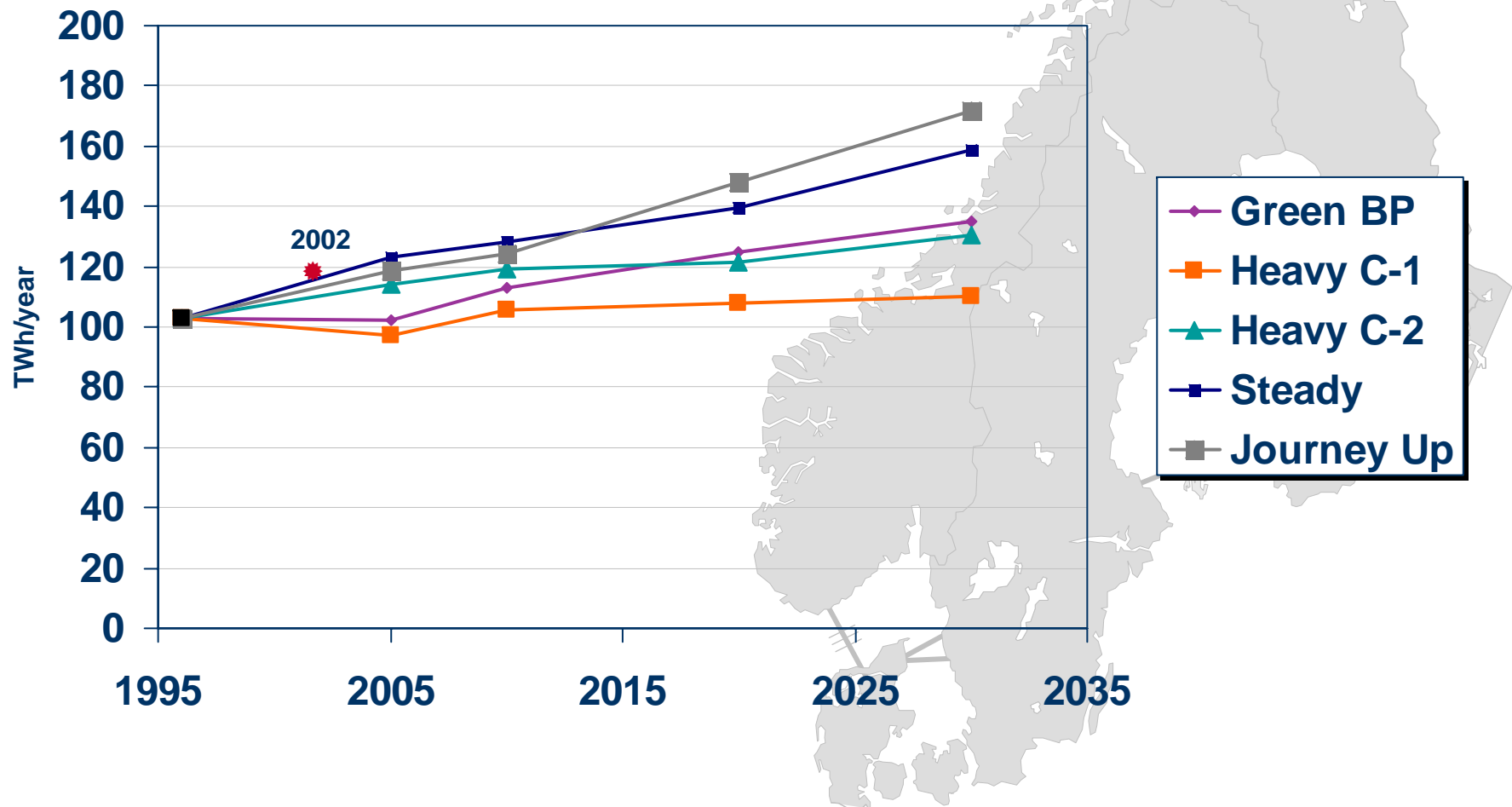
## ■ Uncertainties in demand

- Development of district heating
- Development of natural gas
- Development of hydrogen
- etc.



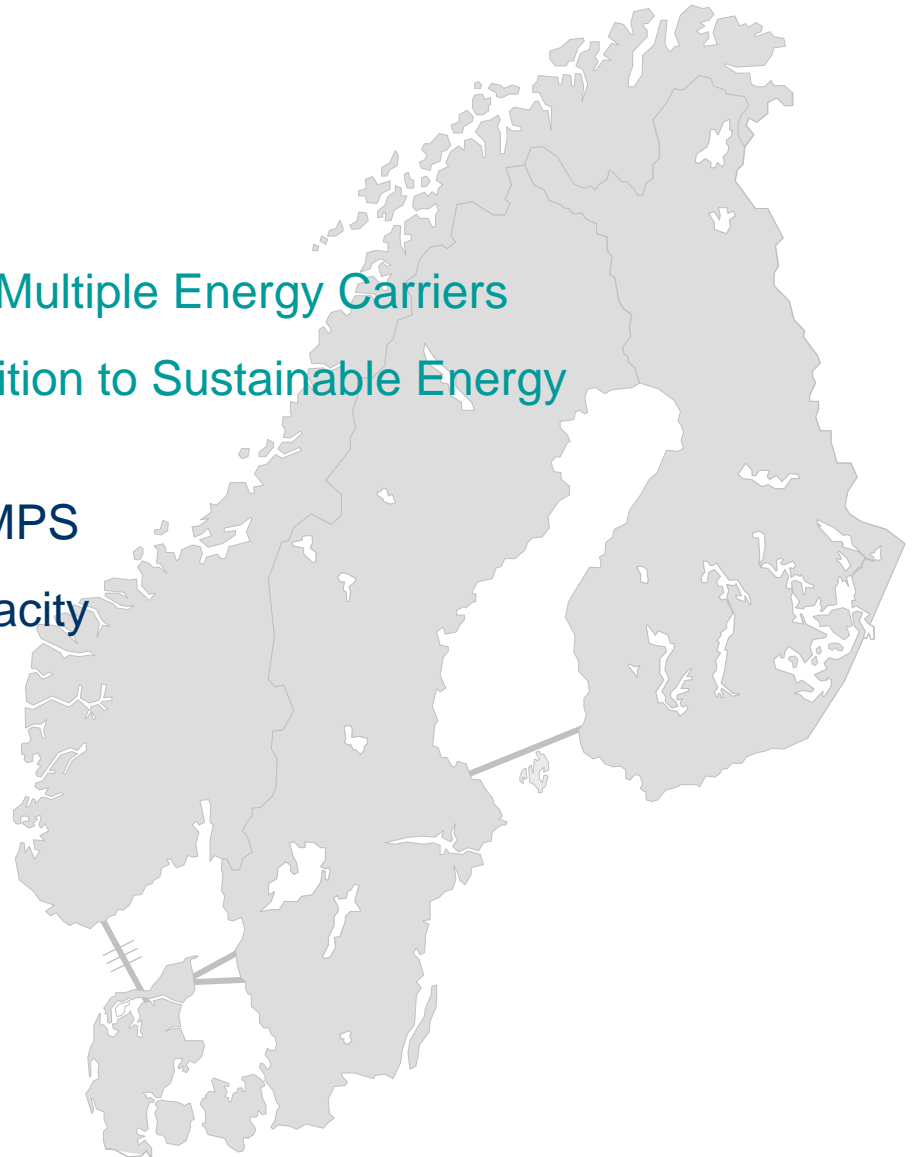
**NOU 1998:11**

## Electricity demand scenarios



## Overview of talk

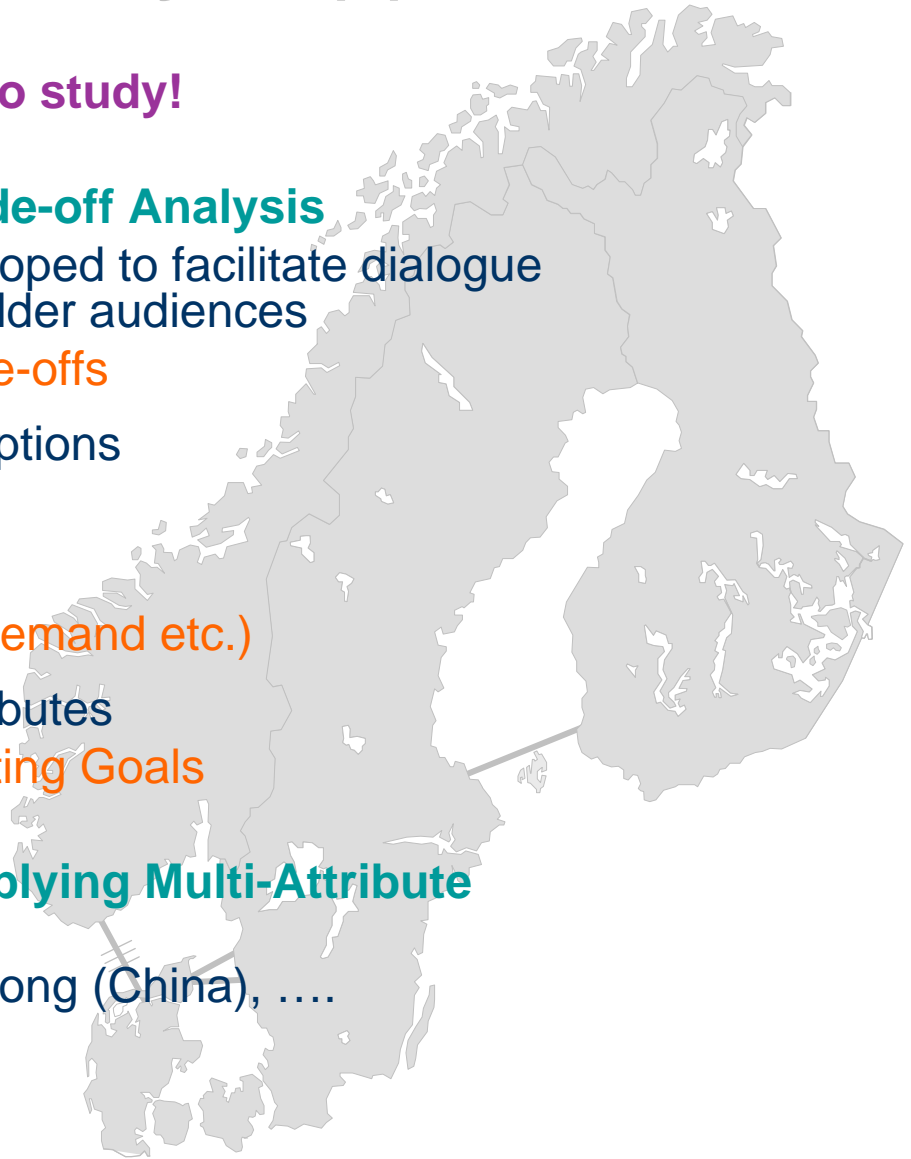
- Introduction to SINTEF
- Planning of Distribution Systems with Multiple Energy Carriers
- TRANSES - Alternatives for the Transition to Sustainable Energy Services in Northern Europe
- Multi-area Power Market Simulator EMPS
- Utilisation of transmission system capacity
- Integration of local energy sources by power electronic converters





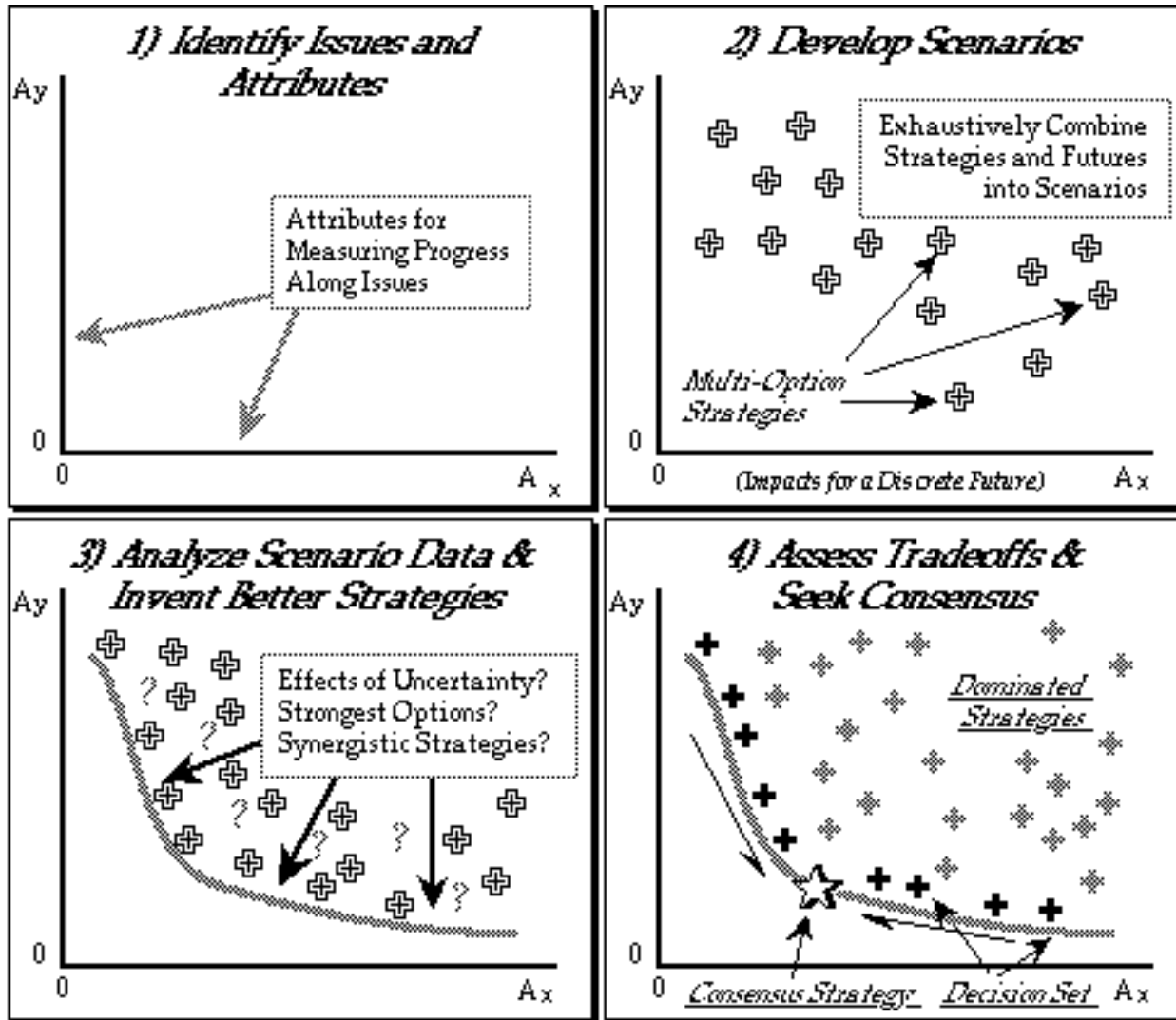
# Multi-Attribute Trade-Off Analysis (1)

- **TRANSES: Not just another scenario study!**
- **Scenario-Based Multi-Attribute Trade-off Analysis**
  - Scenario planning approach developed to facilitate dialogue and learning among multi-stakeholder audiences
    - Graphical presentation of trade-offs
  - Large Number of Technological Options
    - Multi-Option Strategies
  - Large Number of Uncertainties
    - Multiple Futures (fuel prices, demand etc.)
  - Large Number of Goal States/Attributes
    - Multiple Stakeholders, Conflicting Goals
- **MIT has extensive experience in applying Multi-Attribute Trade-Off Analysis**
  - New England, Switzerland, Shandong (China), ....





# Multi-Attribute Trade-Off Analysis (2)



Source: SR Connors, MIT

# Multi-Attribute Trade-Off Analysis (3)

## ■ Features

- Helps facilitate stakeholder dialogues
- Identifies “Good” and “Bad” strategies
- Identifies competing/complementary sets of options
- Recognizes different “Deployment Schedules” of different options
- Identifies “Robust/Flexible” versus “Optimal” strategies

## ■ Supported by

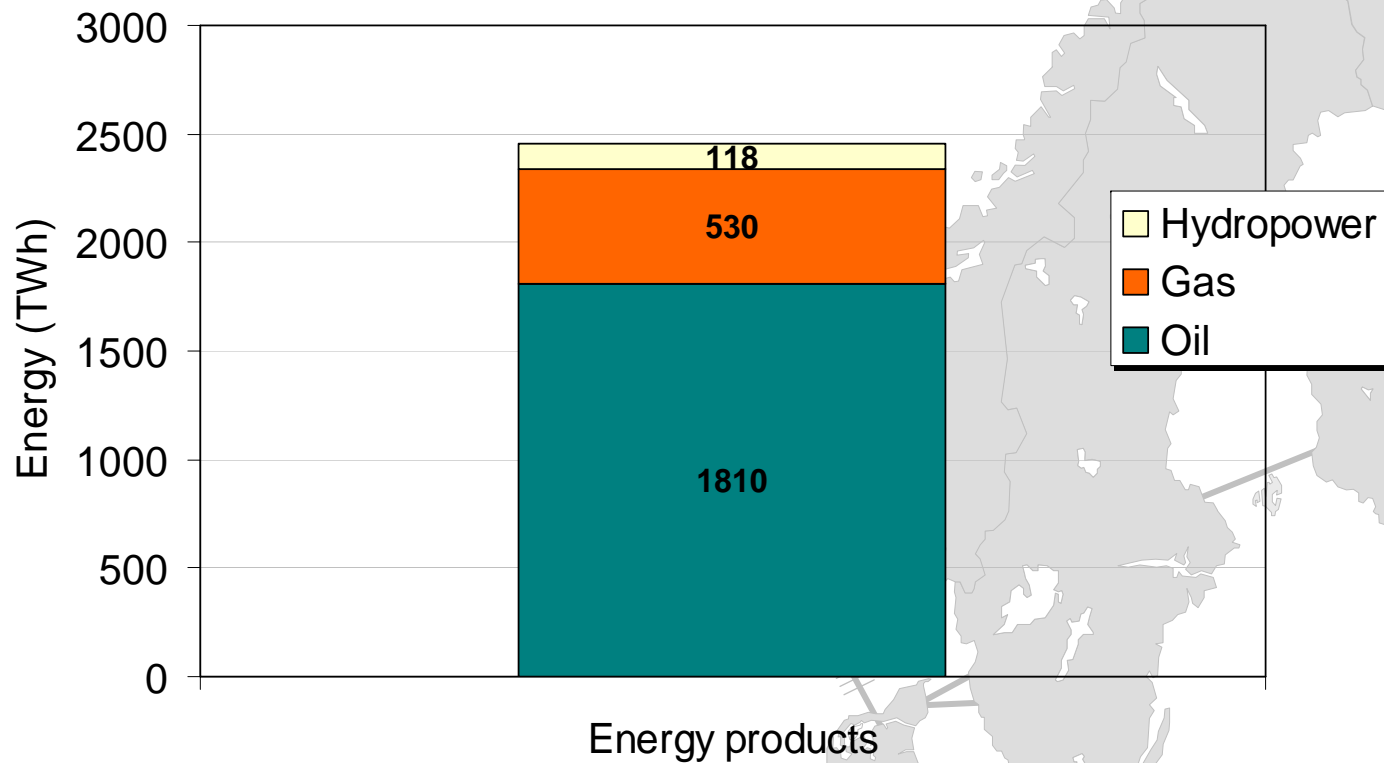
- Simulation and optimisation tools
  - E.g. EMPS model, Markal, Prosym, others
  - “Analytical package” still to be determined
- Stakeholder workshops
  - Emphasize stakeholder interaction and dialogue

## ■ Challenges

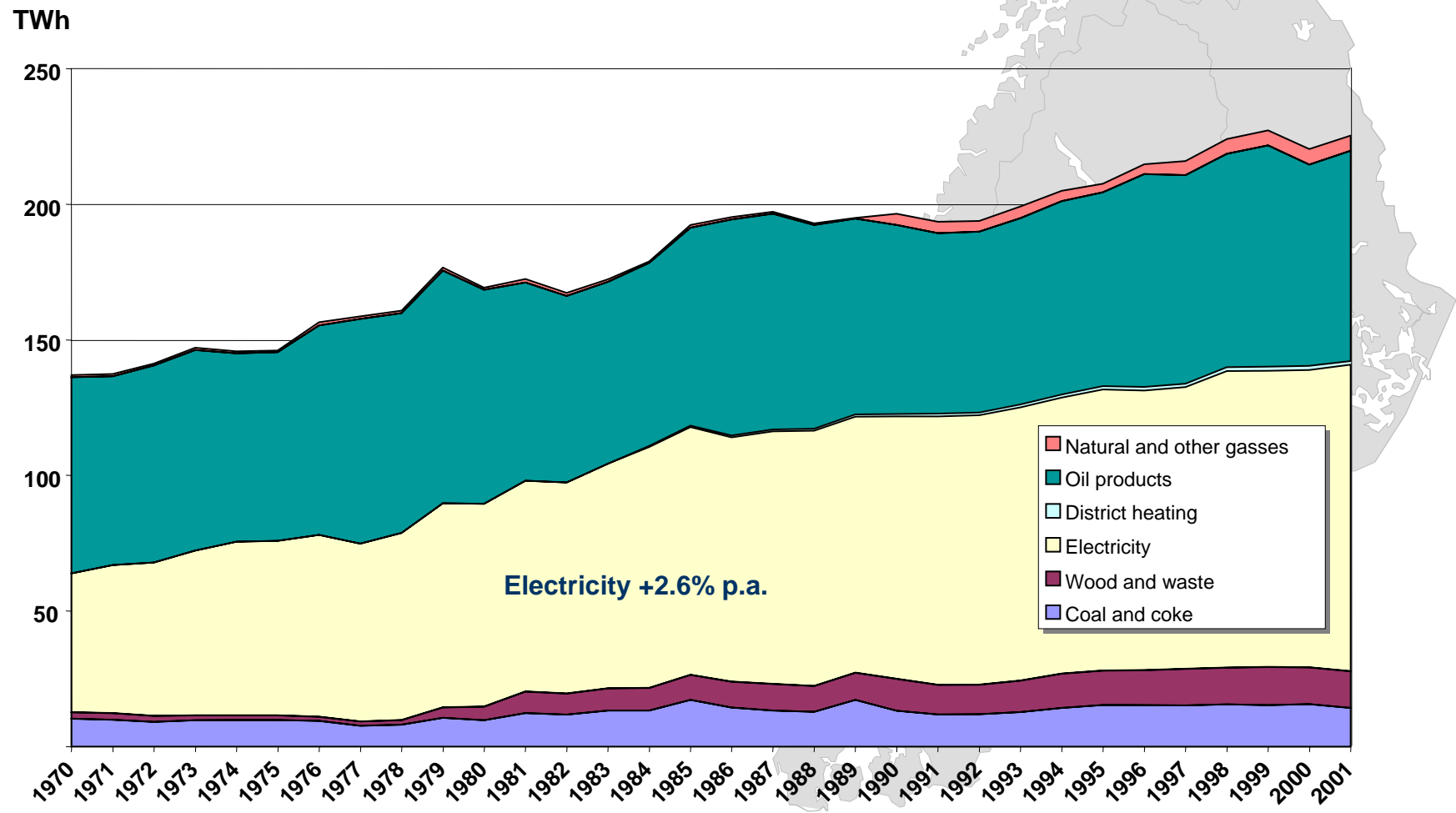
- Market aspect
  - Decentralised planning, multiple decision makers
- Consistent representation of investments
  - Market driven, high risk



# Energy products of Norway 2001



# Energy consumption in Norway 1970 - 2001

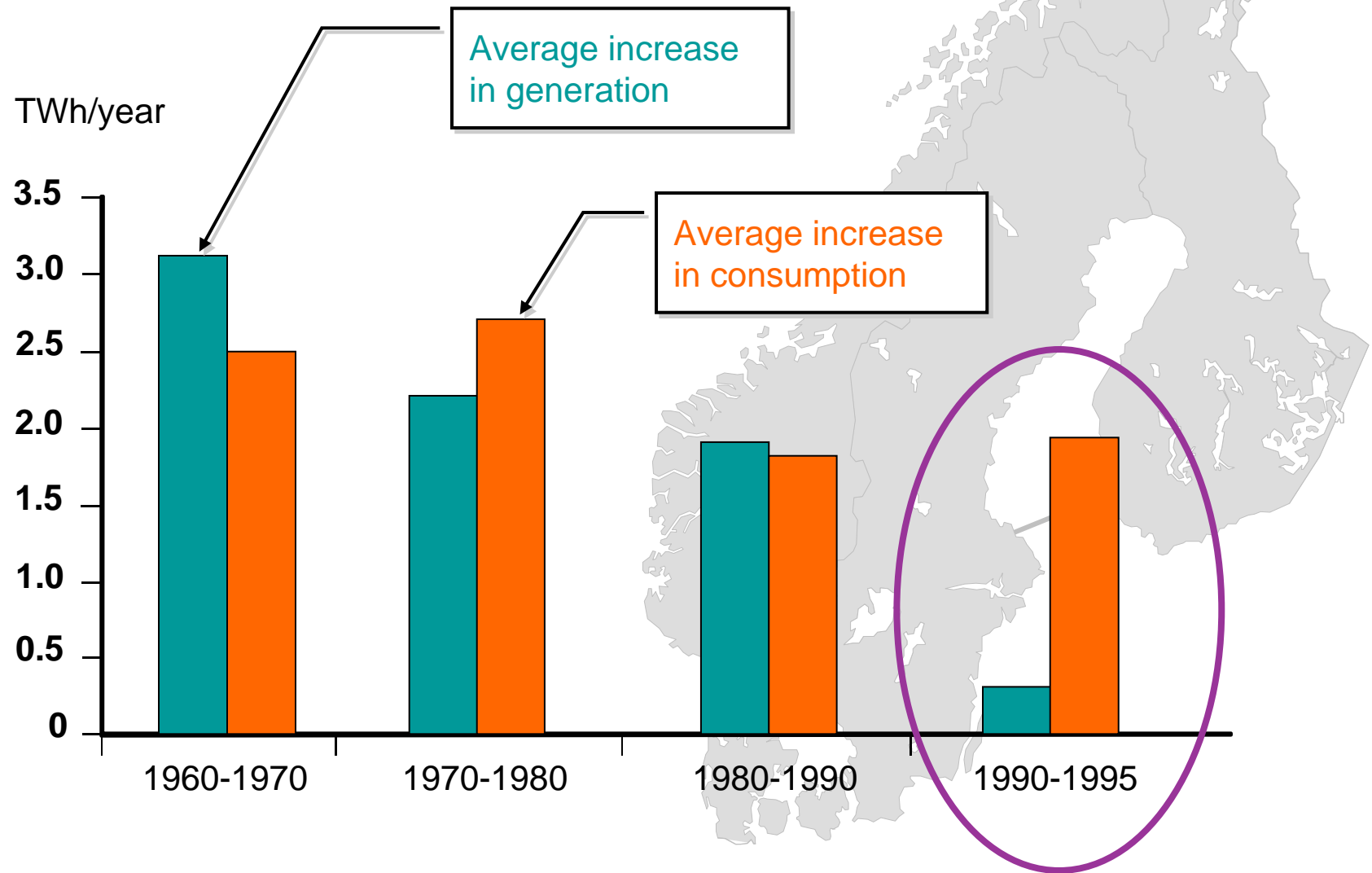


# Residential electricity consumption in Norway (%)

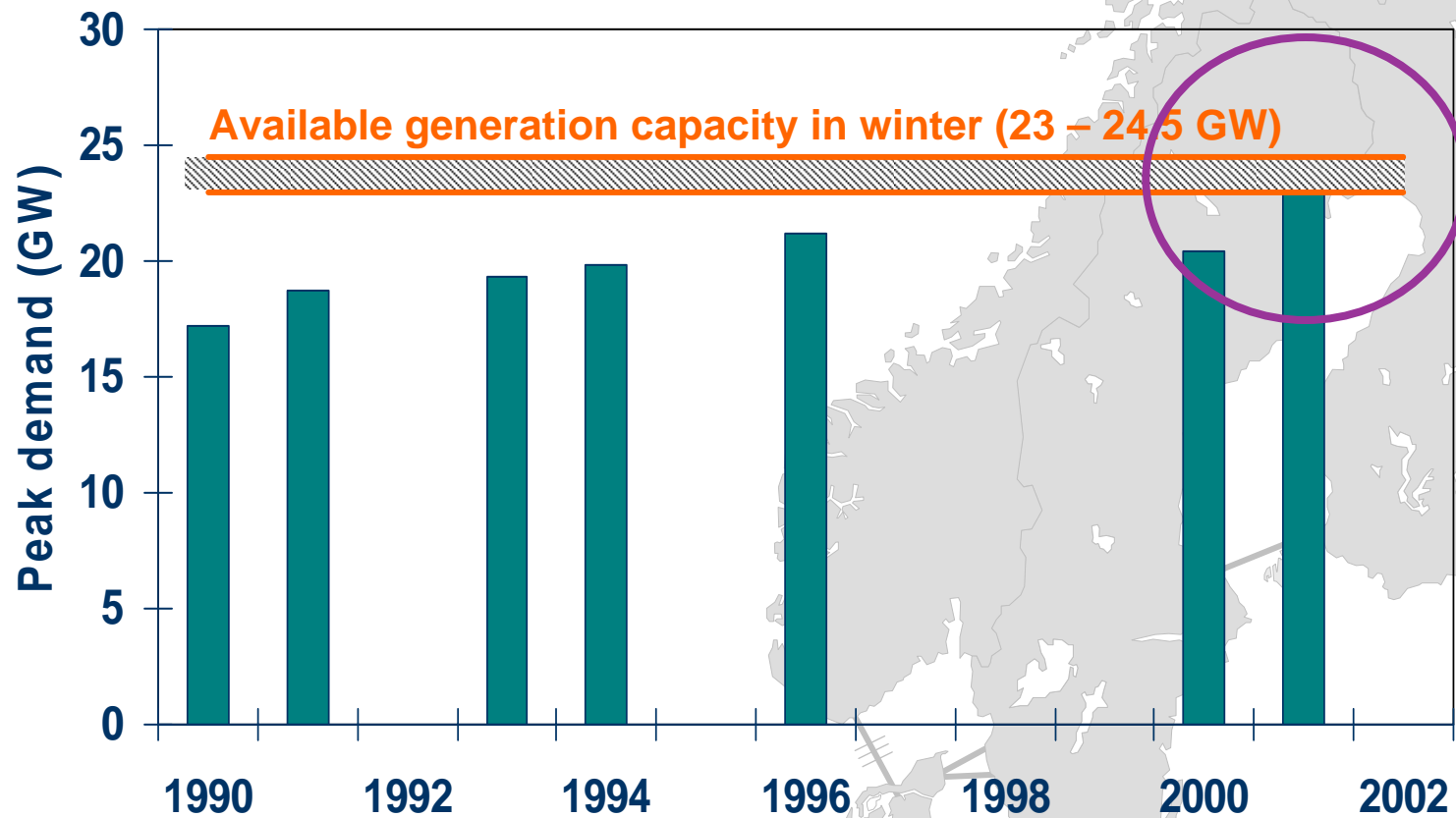
Space heating	41
Hot water	24
Lighting	11
Cooling	8
Cooking	4
Washing	3
Drying	2
Other equipment	7



# Annual increase in generation and consumption 1960 - 1995



# Peak demand records 1990 - 2002



# Existing demand scenarios

- **SINTEF 1996**
  - Energy +1% p.a.
  - Peak power +1.2% p.a.
- **NOU 1998:11**
  - 'Green Brainpower' +0.8% p.a.
  - 'Climate Road' +0.2-0.7% p.a.
  - 'Steady Course' +1.3% p.a.
  - 'Long Journey Up' +1.5% p.a.
- **Nordel area:** +8% from 2000 to 2010





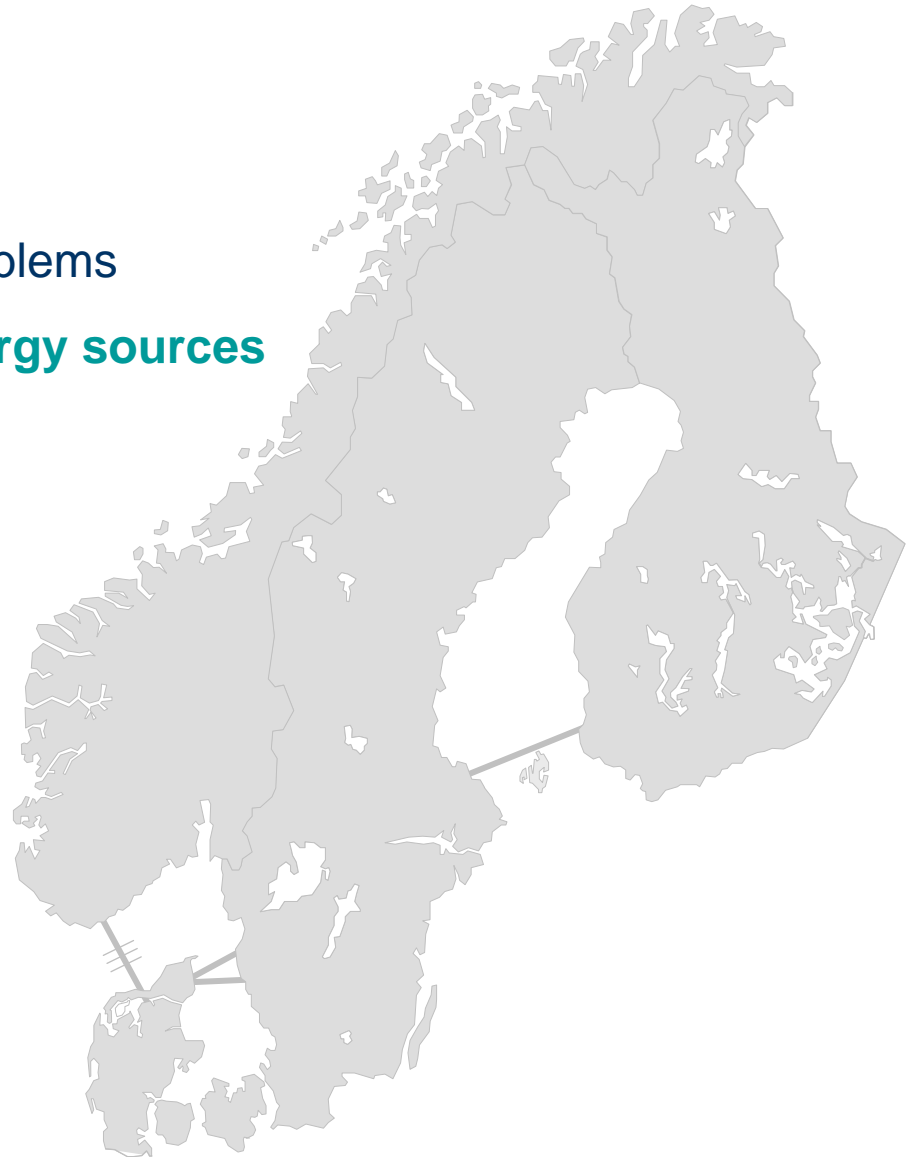
# Supply options (1)

- **Hydro power**
  - Politically and environmentally controversial
- **International electricity exchange**
  - European markets?
  - Emissions trading and certificate markets?
- **Conventional gas power**
  - Politically and environmentally controversial
- **Gas power with CO<sub>2</sub> removal**
  - High investments and reduced efficiency
- **Direct use of gas**
  - Expensive infrastructure
  - Environmentally controversial



# Supply options (2)

- **Wind power**
  - High potential, but not without problems
- **District heating with renewable energy sources**
  - Expensive infrastructure
- **Biomass and waste**
  - Currently only heat generation
  - Waste is paid fuel!
- **Hydrogen**
  - Promising technology
  - Expensive
  - *Not an energy source!!*



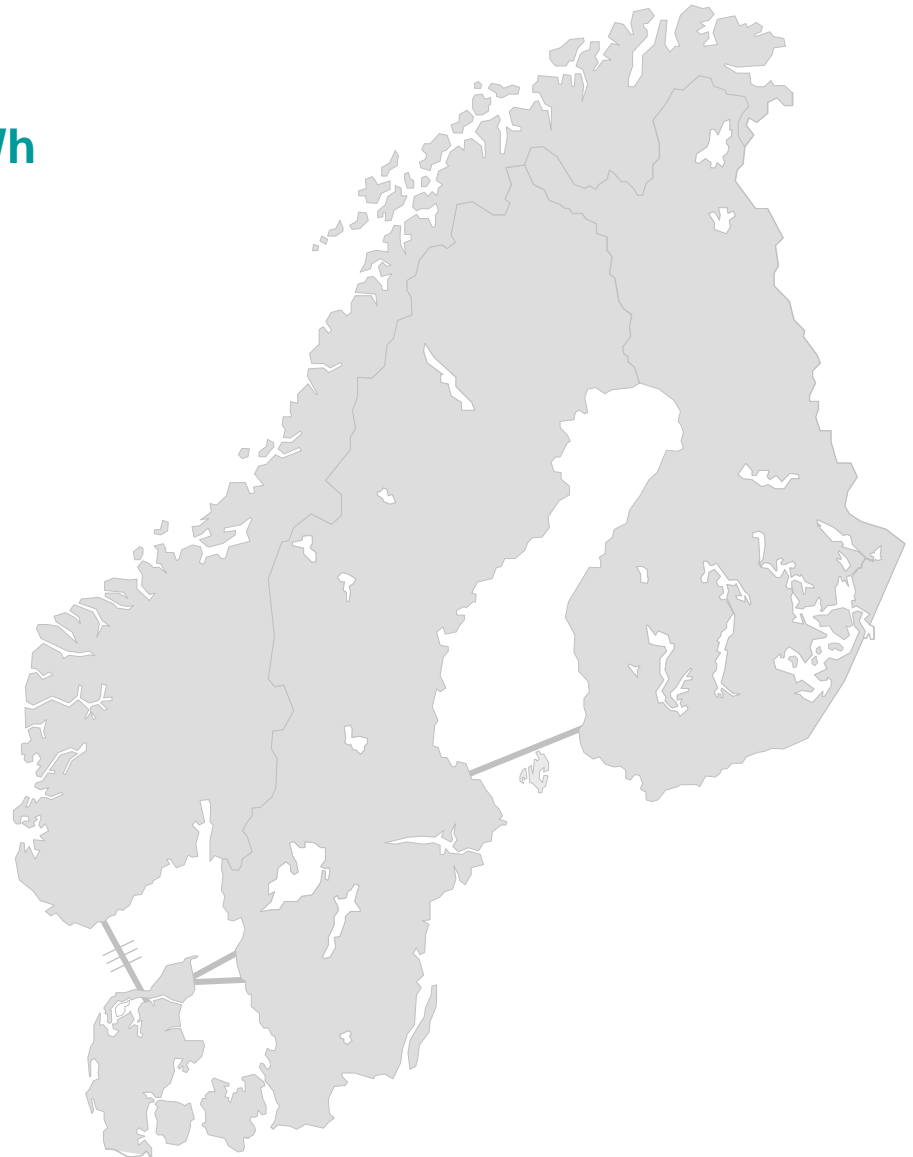
# Demand side options (1)

- **Local energy studies**
  - Demand forecasts
  - Resource mapping
  - Supply and infrastructure
- **Local generation**
  - Utilize electricity and heat
- **Heat pumps**
  - Alternative for heating, but increases dependence on electricity
- **Passive (thermal) solar systems**
- **End-user flexibility / Demand side bidding**



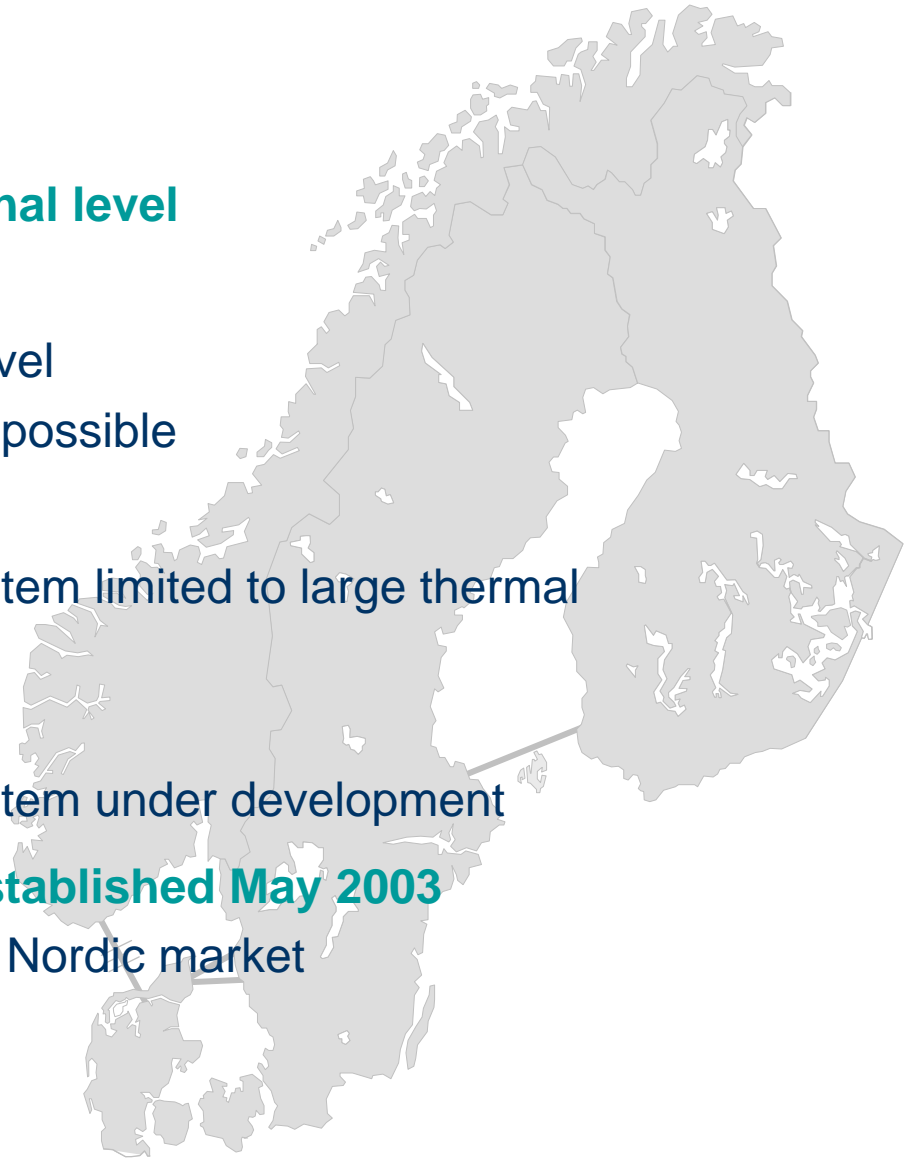
# Demand side options (2)

- **Power intensive industries 30-35 TWh**
  - Selling power “back” to the market
  - Increased efficiency (kWh/NOK)
- **Transport sector**
  - Main source of CO<sub>2</sub> in Norway
- **Building locations**
- **New building codes and techniques**
  - Less effect than expected
  - Slow turnover of buildings



# Climate issues

- **Global, regional (Europe) and national level**
- **Kyoto protocol**
  - GHG emissions related to 1990 level
  - Joint international implementation possible
- **EU directives**
  - Pre-Kyoto GHG permit trading system limited to large thermal power plants
- **National directives and incentives**
  - Pre-Kyoto GHG permit trading system under development
- **Swedish green certificate market established May 2003**
  - Possible development to common Nordic market



# Nordel Elspot prices 1995 - 2003

Weekly average (NOK/MWh)

